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The Organization of Information for Logistics Decisionmaking

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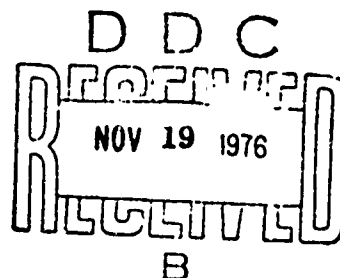
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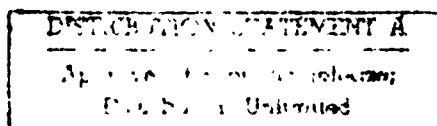
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THE ORGANIZATION OF INFORMATION
FOR LOGISTICS DECISIONMAKING

Murray A. Geisler
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INTRODUCTION

This survey paper was prepared for the session on logistics data collection, representation, and analysis, which covers a wide subject area. Therefore, the material that can be presented must be narrowed, or at least focused. To help in this endeavor, the general theme selected for this paper is the organization of information for logistics decisionmaking. Even this focus is quite broad, and the paper will be specialized further in terms of the subject matter in logistics that is stressed. The use of information in logistics decisionmaking is itself an evolving one, which has its own foundations in many disciplines. Some of the early work in logistics draws heavily from statistics, particularly of the descriptive kind, such as portraying frequency distributions and endeavoring to determine the probability law that seems to describe the demand for spare parts. Such descriptive work provided very useful insights into the nature of logistics problems. For one thing, it led to the general notion that demands for logistics resources are highly variable in both frequency and quantity. This early work also indicated that the costs of logistics resources vary considerably.

Other insights helpful in early logistics research came from economics, with efforts to apply the theory of the firm to logistics situations. These concepts dealt particularly with notions of marginal analysis and marginal productivity. These generalized concepts were helpful in the development of inventory theory, and in the recognition that logistics resources can be traded off against one another in order to attain specified objectives at lower cost.

Of course, the techniques of operations research have had their major role in logistics, and these techniques make heavy demands upon data systems and the processing of such data with the assistance of

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computers. Much of this discussion will center around the period during which operations research helped to develop our understanding and progress in logistics.

The survey thus has the following structure. It contains a number of illustrations from logistics on how information has evolved in its role for decisionmaking. The illustrations cover a few of the earlier uses, with some indication of how these uses have evolved into more complex requirements. The illustrations are then followed by an overall perspective on the current state of the field, with some discussion of where the challenges now exist.

The overall survey is supposed to cover the subject of data collection. This is a very large topic, and it involves methodological and even technological issues. As will be seen, this subject will be treated in the context of the specific examples rather than trying to treat the subject in its entirety. However, a few comments might be made on the data collection area to indicate its content. Data, and hopefully good data, are the essence of logistics management. So much hinges on inventory knowledge, be it of people or things, and the transactions that occur with such logistics resources. Earliest progress on data collection both in inventory and transactions was made in supply, maybe because the counting and control over inanimate objects is a much easier operation than the counting and control of people, such as in maintenance.

In a similar manner, the first uses of computers were made in the supply area, and as a whole, this area has progressed further than others not only in the data collection process, but in the general level of logistics management. However, even in supply, there are conceptual and definitional issues that affect the data collected. Thus, there is the perennial question of the meaning of demand. Typically, the data collected identify "issues," which in concept is different from "demand." Efforts are made in some data collection systems to obtain demand data, usually in addition to issue data, but these lead to complex coding and programming problems, with consequent costs and arbitrariness in the data obtained.

The reporting of maintenance manhour data, which is fundamental to maintenance management, is affected by various biases. Since these

data are used to evaluate and justify maintenance manpower needs, there is the persistent feeling, with some evidence, that such numbers tend to be inflated in order to report that people are kept busy. Aside from having its effect on determining realistic manpower requirements, biased data can have their unfortunate effect on other logistics policy issues, such as where maintenance functions can be economically located.

This interaction between data collection and reporting, and institutional behavior, means that logistics data cannot be treated as abstract numbers of objective information. The user of such data must be familiar with the institution and the incentives that affect those who report the data, and this knowledge must be an integral part of the interpretation that is given to results obtained from the use of such data.

Data collection also deals with such subjects as forms, consistency checks, and in certain areas with the possible use of new technology in collecting data. Some of the problems created by the availability of this new technology will be raised subsequently in this survey, but there are also certain logistics areas where it is clear that the existence of new capabilities could be most beneficial. The reference in this case is the supply distribution function in logistics. Studies of supply pipeline data indicate that the addition of faster means of transportation has not necessarily led to much reduction in pipeline times. The reasons for this result seem to lie in the delays incurred as the resupply action passes from one phase to another. Often these delays are associated with the paperwork involved and the manual actions required by the people in the process. Technology involving special encoding and recording devices has been tried to facilitate the recording of the paperwork and the movement of the cargo through the successive stages of the pipeline, with some success. It does look like a promising area, but it is just one of many in which technology can contribute to the data acquisition area, and at the same time, facilitate the logistics process.

The remainder of this survey will concentrate on the other topics in the area: representation and analysis, with the focus on the theme of the organization of information for logistics decisionmaking. This writer's experience in logistics in the past 20 years has been almost exclusively confined to Air Force studies. Consequently, the illustrations

deal with the Air Force logistics system and aircraft. However, it is believed that the nature of the problems discussed, the results developed, and the current state of the field are quite general in their relevance to the other services and to the theory of logistics, if such can be assumed to exist as an entity.

SUPPLY ILLUSTRATION

In the early days of supply and inventory analysis, a basic insight was developed with respect to spare parts used on such weapon systems as aircraft. This knowledge was gained through a special data collection system used by the Air Force in the early 1950s to help provide insights into the inventory management problems then being encountered with the B-47 aircraft. From these special data, frequency distributions of demand over substantial periods of time, such as a year, showed that relatively few items were demanded, and that of those that were demanded, a very few accounted for the bulk of the demand generated. This experience varied from earlier supply behavior, in which for categories such as food, fuel, clothing, etc., the demand or usage tended to be comparatively stable, so that the terminology "days of supply" was standard in supply manuals and statements about supply requirements. However, such terminology does not fit very well the sporadic and variable demand of spare parts. Only in recent years have some of the official publications dropped the notion of days of supply in dealing with spare parts stockage.

This aircraft demand analysis led to the use of probability models for setting supply policies. Efforts were made to fit probability models to observed demand behavior. The Poisson distribution, with its single parameter, was an early favorite, followed later by the negative binomial, compound Poisson, etc. These more complex demand models were intended to reflect uncertainty about the demand parameters, as well as the variability in demand itself related to the stochastic nature of the process.

These probabilistic insights led to the notion that the inventory problem was one of providing a given amount of supply protection at minimum supply or system cost or maximizing the supply protection for

a given supply budget. Such formulations were made in the early 1950s. The so-called flyaway kit or allowance table were early favorite models and applications of these supply insights. One continuing difficulty with these models--and it persists today--is the so-called range vs. depth problem. Since so many of the items have zero demand in any base period, what assumption should be made about the demand parameter for such items? The use of a compound Poisson or negative binomial distribution helps to provide a model to reflect this dilemma, and it seems to work relatively well. This problem also helps to highlight the system point of view that needs to be taken with supply or inventory policy.

Because of the high uncertainty attached to the demand parameters of most spare parts or line items, the inventory manager must view the supply management in a system context. He cannot guarantee inventory availability item by item under budget and space constraints, but he can only aspire to a level of supply effectiveness for the given weapon system or group of items. Thus, the expectation is that certain of the zero demand items in one year will have a demand in the next year. Since inventory may not be on hand for all zero demand items for most inventory systems, there will be stockouts, but for the system taken as a whole, a given percent of demands or some other related index of supply effectiveness is expected to be satisfied.

The supply data analysis problem has also dealt with the question of an adequate performance measure for supply. Many have been developed and used: fill rate, stockout rate, backorder days, etc. In one way or another, these measures are themselves proxies for more comprehensive measures of supply performance, such as NOR_s (Not Operationally Ready for Supply). The question of which of these measures to use tends to be determined by validity, custom, ease of computation, and the particular mathematical formulation involved. Certain of the measures have mathematical properties that facilitate the use of optimization techniques, and others seem to provide an inventory policy that is closer to the objective function deemed most realistic for supply management.

Aside from probabilistic models to reflect demand behavior, efforts

have been made to employ demand forecasting techniques, especially various kinds of smoothing formulas. The success with these techniques in forecasting demand for aircraft spare parts has been spotty, probably because of the generally low demands for such spare parts. The particular smoothing formula does not seem to make that much difference in the effectiveness of a supply policy. The recognition that the inventory process needs to be considered in a probabilistic context, and that the problem is one of resource allocation under uncertainty, seems to contribute much more technically and operationally to inventory management systems involving stochastic demands.

The design of computerized inventory systems has also reflected the knowledge that demand for many items seems to be low and erratic. This insight has led to the notion of having current centralized inventory information for control purposes, so that assets can be responsively moved around the system, from one location to another, as demand causes changes in inventory levels or as new assets enter the system. This kind of centralized management seems to be especially well suited to the so-called high-cost items because of the limited quantity of such items that are procured for inventory purposes. Such control systems must deal not only with the distribution problem, but with the component repair problem as well. This situation requires control systems with multi-echelon capabilities, since current logistics structures permit both stockage and repair at several echelons.

MAINTENANCE EXAMPLE

A major insight in maintenance developed a number of years ago in the late 1950s when it was clear that the data available for aircraft maintenance management lacked some critical data elements that are necessary to obtain better control over scarce aircraft and maintenance resources. These data elements included the job start and job stop times and the number of men involved in a maintenance task. Additional important information included the reason for jobs being delayed, either in starting or in continuing to completion.

It took a number of years and much demonstration, especially through field tests, to secure the inclusion of these data elements

into the USAF Maintenance Management System (as contained in Air Force Manual AFM 66-1). Aside from the need to demonstrate improvement in management, there is always the difficulty present of introducing change into large organizations, with the need to secure agreement among all commands, to change the instruction manuals, and to print new forms in the millions. All of this effort takes time.

With these additional data elements as part of the AFM 66-1 system, it is possible to produce time traces that show the minute by minute maintenance status of an aircraft at base level. The focus of the maintenance manager is on the maintenance status, and the time trace can show if an aircraft is in maintenance, with no maintenance being performed on the aircraft. This kind of display is important because the presumption is that the goal of a maintenance organization is to complete maintenance on a multimillion-dollar aircraft as rapidly and as efficiently as possible, and management should be concerned if the display shows that substantial periods of time occur with no maintenance being performed. This type of display can be used to show the length of delay as well as the reasons for the delay. At this point, the full benefits of these displays are not being realized because they do rely on computer programs that have not been made a standard requirement for all Air Force organizations. However, they have been used in many test situations.

Such display information tends to be diagnostic in nature. Over time, it helps to identify the amount of delay and the causes of delay. It helps management to make changes in resource allocation, work schedules, inventory policy, etc., that can help to reduce the delays, and thereby presumably speed up the turnaround time for aircraft passing through maintenance. Various scheduling rules and goal-oriented techniques have been developed for use along with these displays, but these methods have been primarily exploited in research and test situations.

The diagnostic usefulness of such display information needs to be supplemented by other decisionmaking tools, particularly models that provide guides to longer term resource allocation. Such planning models are especially useful in dealing with steady state or essentially equilibrium conditions. They recognize that there must be a tradeoff between

maintenance responsiveness and the resources assigned to maintenance on a long-term basis. Models of this nature can be quite aggregate or they can be highly detailed.

Both SAMSON and L-COM, two major modelling efforts done at Rand and the Air Force in the mid-1960s, are examples of detailed simulation models. These models deal with the tradeoffs between operational capability and logistics resources. They made demands on the standard data systems for detail that was not then available. Thus, it was early experience with SAMSON during the mid-1960s that stressed the need for the augmented AFM 66-1 data system, particularly on team size detail, for each maintenance job. And L-COM, which is a network model, required construction of the aircraft maintenance task networks down to the black box or module level, and to specify for each task the specific maintenance AFSCs (Air Force Specialty Codes) used. Both these models, particularly L-COM, have been used in the Air Force, and for purposes beyond those originally intended. It is understood that L-COM has been validated against real world experience with sufficiently satisfactory results that it is now being used to develop resource requirements for maintenance personnel, and ground support equipment, under a variety of operational conditions for mature weapon systems, as well as for some newer weapon systems.

Thus, models have also helped establish additional data collection needs, because such data are necessary to permit the use of such models in planning and other functions of management. Realization of the full benefits from these additional data elements in day-to-day base-level operating management in performing such activities as maintenance scheduling, job dispatch, manpower control, etc., will have to await further progress in the availability of computer-based maintenance management and control systems.

SCHEDULING EXAMPLE

A significant tool for resource allocation is known as scheduling. By scheduling we mean the assignment of resources over time in such a way that stipulated goals of the organization are being satisfied. Scheduling can be done for varying time periods. Some schedules are

prepared to cover a month's activities, giving day-by-day detail. Others are prepared for each day to show the specific actions and assignments for the day.

One key type of scheduling problem important to logistics is that concerned with the operation of aircraft at airbase level. Within a command, such as the Strategic Air Command, bomber aircraft are flown for aircrew proficiency training. The scheduling work involves two major components: (1) the so-called operations scheduling which involves the specification of the training to be done on each sortie, taking into account the status of training of each of the crews; and (2) maintenance scheduling, which involves the selection of aircraft for each training mission and the scheduling of the maintenance tasks and resources for making the aircraft mission-ready.

This discussion is oriented toward this kind of scheduling problem because it contains most of the complex elements that must be treated in making progress on scheduling, especially in using the computer, because the current capability, at least within the Air Force, is dependent on manual forms of scheduling. Such limited computational capability restricts the options open to the scheduler in seeking to improve the quality or performance of his schedules.

The scheduling theory and its implementation for operations-maintenance scheduling are in a relatively early and developmental state. This work is truly a research and development problem of the 1970s, with antecedents in the late 1960s. Its complexity arises because a schedule must satisfy both objectives and constraints, and these are sometimes mutually contradictory or at least interacting in relatively subtle ways. Scheduling of aircraft operations for training purposes, for example, has historically been a heuristic process, with much of the work done manually. The result is that scheduling is recognized as a tortuous process that permits very little examination of alternatives in terms of objectives or allocation of resources.

Current aspirations for advancing the state of scheduling capability are to provide a man-machine environment in which the scheduler can experiment with alternative schedules, trying to fit in various circumstances that could affect either the aircraft status or the people

involved in operations and maintenance. Since such a nonspecific condition characterizes scheduling, it is necessary to provide flexibility to the scheduler and to permit him to give more or less weight to different parts of the scheduling interactions. This manipulation of the schedule is a way of making goal-setting decisions and observing the consequences on the schedule. This weighting of different aspects of the schedule basically relates to notions of utility as perceived by the scheduler. The scheduler tries to bring in his utility preferences to reflect specified objectives or requirements, but because of constraints inherent to the performance of the scheduled activities, the heuristic process must take over to resolve the interactions that result. However, the resulting schedule may or may not please him, so the scheduler needs a capability to change it.

The scheduling process is thus a continuous one, since conditions and even goals themselves might change, so that the scheduler is always assessing the situation against these goals, seeking to make progress in efficient and consistent ways. This effort is aided by various display techniques and analyses reflecting status and problems.

This type of scheduling process, with its support of choices, needs a rich data base. In the case of combat crew training, it requires much detail on the status and characteristics of crew members, the composition of training curricula, the outcomes of training exercises and tests, and much information on each training aircraft as well as the resources used to maintain the aircraft.

In the initial formulation of the scheduling process, it had been thought that the development of the underlying information system could be undertaken independently of the development of the scheduling algorithms. This assumption was made because it was felt that the existence of a data base that could be queried on-line would be a useful tool for the managers, and it could also be done relatively early in the development process. However, the interlocking nature of the queries and the scheduling process has become so evident that the old concept has been dropped, and it is now accepted that there must be the concurrent development of the scheduling algorithms and the associated data system.

Scheduling has significant implications of data presentation and

analysis for a variety of reasons. For one thing, it is viewed as an interactive process between man and the computer. This means that access to the computer should be made relatively simple and easy since the schedulers will not typically be computer specialists. Second, output from the computer in terms of displays should be easy to read and be helpful in providing ways to improve schedules. The art and technique of displays in the man-machine process deserves special recognition in successful implementation of scheduling systems.

Basically, what it would be nice to have is a scheduling black box into which the scheduler puts his objectives or utility preferences related to the tasks to be scheduled, and out of which come schedules that he can modify rapidly as he tries to resolve the conflicts in goals and constraints. The black box would contain all the current data, heuristics, special constraints, etc., needed by the scheduler to obtain feasible schedules, and his efforts are then focused on improving the schedule's quality. This kind of system is not easy to achieve, but if it could be done, the scheduling capability will have advanced a great deal.

"What if" questions should also be made easy in an interactive scheduling system. The purpose of a schedule is to accomplish certain objectives, and so a schedule, if followed, can show outcomes which serve as responses to "what if" questions.

As is clear, this scheduling theory and study effort, along with its information system complement, is an evolving and not particularly advanced research area. This means that much of the early effort must be undertaken by means of experimental and evolutionary prototype systems that will help to suggest further steps in progress to truly implementable systems that have the capabilities required in an operating situation. From exposure to various studies on scheduling and other types of logistics management systems involving man-machine interactions or other complex organizational decisionmaking activities, the importance of using prototypes to learn about the desirable and undesirable characteristics of such systems cannot be overstressed.

DATA ACQUISITION

The history of logistics data has been strongly focused on the process of data acquisition. The creation of systems in the Air Force such as AFM 66-1 and AFRAMS (The Air Force Recoverable Asset Management System) has been marked by management efforts to ensure complete reporting, accurate data, and hopefully, effective use of the data products.

The advent of built-in automatic reading and recording systems (usually referred to as AIDS, standing for Airborne Integrated Data Systems) has made it much easier to collect data on aircraft conditions in flight. One intent in using AIDS is to reduce aircraft downtime by more rapid reporting and diagnosis. In matter of fact, with the introduction of AIDS, the situation may be becoming one of data congestion, which could add significantly to the costs of these systems because of the heavy requirements for data processing. With so much data to analyze, it is understood that difficulties are being encountered in using these data rapidly for diagnostic purposes. Such techniques as trend analysis do not yet seem to have the predictive properties that had been anticipated, except in limited instances. Furthermore, it appears as if the problem of using these data for diagnostic purposes may call for basic kinds of engineering knowledge that may not yet be fully in hand.

It seems as if the problem is one of developing greater understanding about the basic failure processes so that a model of the physical environment can be used to generate the data requirements and to interpret the diagnostic data in ways that improve logistics support. There has been some experience on the problems of data collection oriented toward these engineering and logistics studies through special field tests on specific aircraft types and in particular operational environments. For the time being, it seems that these diagnostic efforts must be tailored to specific problem situations because of the lack of basic technological understanding about the failure process. Under this learning situation, it is difficult to standardize the analysis process for which automatic systems are typically designed.

The point of this discussion is to raise some questions about the use of expensive and also possibly unreliable sensor or other recording

equipment to collect large quantities of data when more understanding is required to make effective use of the data. It would seem that there is a need to invest more effort into research on failure analysis oriented to explaining the failure process in physical and engineering terms, so that the data and interpretation produced by such recording and testing equipment are valid and reliable, with resulting important logistics benefits.

The logistics implications of what is being said about such automatic recording systems can be illustrated by the following. With the current use of integrated systems, especially in avionics, incorrect diagnosis can cause the removal of black boxes, which when returned to some repair facility are found to function perfectly upon being checked. This means that the repair pipeline contains serviceable modules that tend to inflate demand statistics and pipelines, with consequent increased procurements of extra spares, as well as additional expenditure of manhours, transportation, etc.

Limited experience from previously mentioned field tests with integrated avionic systems indicates that such RTOK (Returned, Tested OK) modules may occur not only because of hardware deficiencies but because of limitations in the software used in AIDS to diagnose and interpret the condition of the individual but integrated hardware elements. It is important to understand whether this inadequacy could reflect an unsatisfactory "model of the world" as contained in the software rules, or whether the diagnostic routines which are also in the software need improvement. Experience with such problems is too limited to provide definitive answers to a situation that involves a combination of analytic, engineering, and logistics expertise. These multidisciplinary problems are becoming more central to analysis, control, and operation of logistics systems.

EXPLOITATION OF DATA VARIABILITY

This technique, which is an ancient approach to data analysis, has been exploited in important ways in logistics. The basic notion in science is that of experimental design. One establishes a design in which the treatments accorded different subjects or objects are varied

in a pre-established way to help evaluate the effect of the treatment on the outcomes being measured. Now, for many laboratory and other controlled situations, this scientific approach can be followed, and it has been very successful.

In institutional or real world situations, such as logistics, where there are complex phenomena in which the interactions are very imperfectly understood, so that it is difficult to establish a so-called controlled experiment, opportunities can be found to exploit the types of variability which occur naturally through the replication of particular events. This approach can be especially useful when one is dealing with problems in which the theory for explaining causes is lacking or not understood. This situation is not infrequent in the logistician's world. In the absence of theory, decisions on physical activities are sometimes made through policy declarations that in effect are subjective determinations of what seems best to do under the circumstances. Unprogrammed or inadvertent deviations from such policy, which could be the result of many factors, provide real world experience that may offer opportunities for evaluating the established policy.

A good example of this experience can be provided from logistics. The time interval between major inspections of an aircraft at a depot is based on policy that contains subjective elements. Changes in the inspection interval are made from time to time, presumably relying on experience obtained in the course of maintenance, as well as the number of aircraft that are in the depot, and therefore the resources that must be provided to this activity. As the interval is extended, fewer aircraft are in the depot, and the maintenance capacity required is reduced. This depot inspection and repair activity is not inconsequential from a resource viewpoint. Therefore, there are good reasons to seek judicious extension of the interval.

As has been said, interval setting and extension is somewhat a subjective matter, and an attitude of conservatism seems to be followed in changing such intervals. For one thing, there is a desire to retain resources, since this provides a hedge against sudden increases in workload. In addition, there is a sense that it is safer to have aircraft

receive depot inspections more often rather than less often. On the other hand, there are worthwhile reasons to extend intervals more rapidly if evidence suggests it should be done.

Turning now to the theme of data variability using the aircraft interval problem for illustration, it had been first thought that it would be necessary to conduct special experiments to get information on possible interval extensions. This would have been expensive and even difficult to do technically, aside from convincing the institution that such experimentation is desirable and useful. However, when empirical data were studied, it was found that through various circumstances there were aircraft that had exceeded the policy interval by varying amounts, some substantially. Thus, by this "accident" the analyst had access to aircraft which had experienced longer intervals than dictated by policy. The analysis of these aircraft, in terms of work to be done, condition, etc., showed no significant difference in their requirements from those which had received their inspections at the specified interval. Consequently, in an empirical manner, there was evidence that it would be appropriate to consider an interval extension.

Obviously, in addition to exploiting existing variability, there is the further option of inducing interval variability, so that experience can be obtained at inspection intervals beyond those specified in current policy. This approach involves experimental design, using induced variability to establish the desirability of extending the inspection interval and the amount of extension. This subject is an extremely complicated one because there is no evidence pointing to one "best" interval, at least from an engineering standpoint. Even the approach taken by the airlines is also an empirical and subjective one. As one looks at airline data and analyzes the way in which intervals have been extended on successive generations of jet aircraft, starting with the Boeing 707, then the 727, and now the 747, one sees a more rapid extension of intervals for comparable stages of life with each of these aircraft.

The study of interval extension opens up other aspects of analysis. When one examines a population of aircraft that is subjected to interval extension, it experiences a so-called "maturation phenomenon." Thus, if the inspection interval is extended from two to three years, it takes

a full six years before all aircraft are on the new inspection interval. Therefore, a decision to move to an extended interval does not subject the entire aircraft fleet immediately to whatever unforeseen dangers there may be in the longer inspection interval. However, there is the immediate benefit from the reduction in resources required, in this case a reduction of about one-third.

It is possible, if trouble develops, to stop the interval extension process, and reduce the interval. Of course, just as it takes time to bring all aircraft up to the new interval, it also takes time to return all aircraft to the old interval. From what has already been said, there is evidence to indicate that interval extension policies tend to be conservative, so that the likelihood of needing to set them back, in the current environment, is small.

This subject of interval extension provides an interesting illustration of empirical data analysis, combined with some relatively modest mathematical modelling of simple dynamic relationships as affected by changing aircraft inspection intervals. Use of this model shows that it takes a long time for the effect of an interval change to increase the inspection interval for the whole fleet of aircraft that go to the depot for periodic inspection. It would be desirable to consider, or at least contemplate, a more dramatic approach to periodic inspection in order to realize more rapidly the benefits of interval extension. One possible way to achieve such a result is to view the depot inspection problem as one of sampling aircraft with different ages, measured in terms of the interval since last inspection. This approach would permit the introduction of interval variability in a systematic way, and it may avoid the lengthy maturation phenomenon which occurs when interval extension is treated as a gradual fleet-wide policy.

Thus, one possibility is that the problem can be approached from a sampling context, recognizing that the appropriate inspection interval is an uncertain or unknown policy parameter. A strategy could be developed in which a relatively small proportion of the aircraft are sent in for inspection at selected intervals, and an analysis made of their condition. Both the proportion inspected and the interval between samplings could be varied depending on the information obtained and

the sampling and inspection strategy followed. It is presumed that the sample size selected would be reasonably small, say on the order of 10 percent, so that if the samples were done annually, this would be equivalent in numerical terms to a 10-year interval.

Such a sampling approach would drastically change the approach taken to scheduled maintenance. Instead of treating depot visits by aircraft as prescheduled opportunities to do work, the particular aircraft would probably be selected randomly from a sample of aircraft that were of a given age or interval since last depot inspection. Such a technique is now being used to obtain engineering data on the condition of aircraft, but it is not tied in an explicit way to the inspection policy. This proposal would combine the sampling policy and the inspection policy into a single process that would affect the scheduled maintenance workload at base and depot, depending on the sampling outcome.

Obviously, such an opportunistic and adaptive approach to depot inspection does call for flexibility in the depot's capacity to absorb changing workload demands, but this is the usual environment in which the depot operates. Time after time, sudden workload demands occur, be they major modifications or special projects dictated by operational requirements. Therefore, if the approach is found to be useful for managing scheduled maintenance, the depot should be able to handle the consequence of some unpredictability in this type of workload.

This illustration is given to show the opportunities for imaginative approaches to old problems. There are other interesting parts to the scheduled maintenance problem, including its relationship to unscheduled maintenance, to modification activity, and to the location of maintenance activities, all of which are deserving of detailed investigation since they could have large impacts on readiness, manpower savings, and changes to the logistics structure.

A PERSPECTIVE

Thus far, this survey has dealt with specific examples of how data affect logistics decisionmaking. One is always tempted to generalize from these specifics to try to obtain an overall perspective on where this effort is tending, hoping that more structured insights will

provide a productive opportunity for progress.

As the examples have indicated, initially much of the focus was on the use of data for analysis, largely statistical, to help identify the key variables of relationships affecting logistics requirements and performance. Such analysis led to the creation of more formal and elaborate models of the phenomena. This work was aided by such concepts as tradeoffs and cost-benefit analysis, as well as viewing logistics as a system. Such views led to the development of models for studying these tradeoffs. Thus, in the inventory area, there has been much interest in the tradeoff between stock levels and resupply time, or tradeoffs among supply, maintenance and transportation of spare parts. In maintenance, among the tradeoffs studied has been that between percent of aircraft NORM (Not Operationally Ready for Maintenance) and the amount of maintenance resources available, taking into account the aircraft activity rates and perhaps other factors.

Such models were actively built and used in the late 1950s and 1960s. Their construction and use were aided by the developing capabilities of computers and various programming languages. These models undoubtedly helped to shape some of the developments with logistics systems and to require the use of more analytically oriented approaches to logistics decisionmaking. Their use also led to a requirement for many military personnel trained in the application of these techniques, so that models are now becoming a more substantial part of the study and analysis process used for internal decisionmaking.

Data analysis helped to shape the contents of models, and in turn, the models helped to determine data requirements that were not already in the ongoing data collection systems. Such data requirements were sometimes embedded in the routine data collection systems, or at times, special field tests or experiments were employed to attain data required for the models.

Most cost-effectiveness models are largely used for planning purposes, that is, they help in those decisions or policies that lead to relatively long-term allocations of resources. The models are also used for sensitivity testing purposes, since the effects of such long-term decisions should be relatively stable over the range of conditions

likely to be encountered in the future.

The next stage in the evolution of the use of information for decisionmaking, and one that is more recent in its general interest, is that associated with management control. These uses attempt to make decisions based on current information, and the impact of these decisions tends to be shorter run in effect. Management control systems involve much interaction between the information system and the decisionmaker on a frequent basis, because the problems encountered are dynamic, requiring the decisionmaker to make constant adjustments to his plan. The scheduling example discussed previously is typical of this kind of problem.

The state of art of management control systems is probably less developed than the traditional analysis and modelling previously discussed. The former subject brings up difficult elements of decisionmaking, such as utility measures and time discounting, that is, the degree to which the decisionmaker is prepared to discount the future in making decisions about the present. These subjective determinations cannot be automated, but rather it is necessary to permit the decisionmaker to introduce his judgment about such factors dynamically into the decision process.

This aid to the decisionmaker must be provided not only through the specific items of information supplied to him, but also through the way in which it is portrayed for his consideration. Information displays, formats of representation, and various triggering or flag devices for alerting the decisionmaker to changed circumstances are forms of data representation that management control systems now require. The techniques for devising these formats and evaluating them are now required as part of this new technology.

These man-machine techniques are in early stages of development because they do involve the interactive activity of man and computer in decisionmaking activity. The principles of this capability involve heuristic processes that must be created as part of the control system design process.

In order for the control system to be useful to the decisionmaker, it is necessary that he have a way to inject his utility function into

the control system, and then observe the results of his actions. Thus the control system itself becomes a set of heuristics that operate on the decisionmaker's utility choices, and then produce resulting decisions and actions. Since the decisionmaker is usually not explicit about his objectives, or the problems are complex, he needs a flexible and responsive control system. Without such capability, the decisionmaker's motivation or ability to use such control systems is not high because they do not seem to fit his needs.

There has been some progress through laboratory studies and field tests on understanding how the decisionmaker in logistics can be motivated to use the computer in his control process. It has also been learned through experience that it is difficult and costly to study this problem with full-blown control systems. Failures with big control systems are legion in the management information and control system field. The limited successful experience with this type of problem suggests the advantageous use of prototypes, which provide a means for system designers to learn how the computer can be most helpful to the decisionmaker by trying to involve him specifically in the design process in comparatively realistic ways. Thus, the man-machine interface is itself a parameter of system design which can vary in different parts of the system and at different phases of the design process, depending on the ability of the designer to meet the decisionmaker's needs. Such insights into the man-machine aspects are required so that the computer's role can be defined in sufficient detail to provide the software, information inputs and outputs, and other design characteristics of a control system useful to a decisionmaker. This statement contains an assessment of many years' observing and working with logistics management systems. It tries to be hopeful and systematic about what can be accomplished, but past realities still indicate difficult experience lies ahead.

From the ranging nature of this survey, it can be seen that the subject has many facets. In the final part, an effort has been made to pull the pieces somewhat together to indicate how the processes of data collection, representation, and analysis interact in logistics decisionmaking. Although much progress and understanding have been achieved, the problems and challenges are still tremendous. The need

for research, systematic study, and appraisal of what has been accomplished and learned will continue. The payoffs in logistics will be both increased support capability and more efficient use of resources.

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